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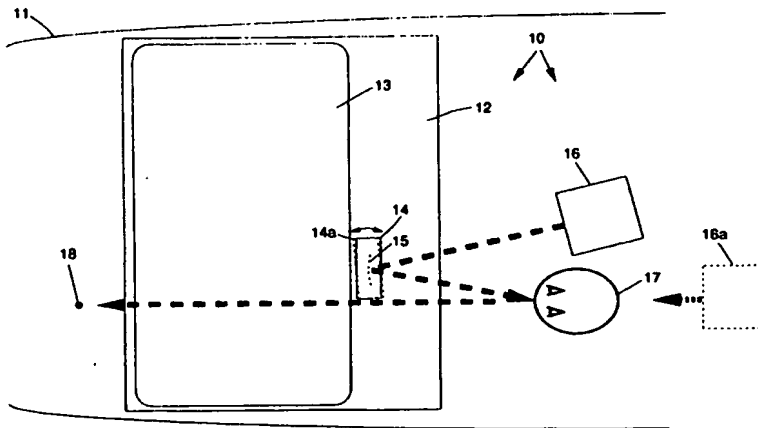
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<p>(21) International Application Number: PCT/US93/08904</p> <p>(22) International Filing Date: 21 September 1993 (21.09.93)</p> <p>(30) Priority data: 07/954,522 30 September 1992 (30.09.92) US</p> <p>(71) Applicant: HUGHES AIRCRAFT COMPANY [US/US]; 7200 Hughes Terrace, Los Angeles, CA 90045-0066 (US).</p> <p>(72) Inventors: BLAZIC, Ernest, C. ; 4860 West 129th Street, Hawthorne, CA 90250 (US). WU, Ning ; 29207 Beach- side Drive, Rancho Palos Verdes, CA 90274 (US). SMALANSKAS, Joseph, P. ; 6382 West 79th Street, Westchester, CA 90045 (US). HOPKINS, Dale, W. ; 11291 Clarissa Street, Garden Grove, CA 92640 (US).</p>	<p>(74) Agents: ALKOV, Leonard, A. et al.; Hughes Aircraft Company, P.O. Box 80028, Building CO1, M/S A126, Los Angeles, CA 90080-0028 (US).</p> <p>(81) Designated States: JP, NO, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).</p> <p>Published <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>	

(54) Title: OVERHEAD HEAD-UP DISPLAY FOR VEHICLE APPLICATIONS AND THE LIKE

(57) Abstract

Overhead head-up display systems that has an image display source located above the operator of a vehicle. The display source may be mounted off-axis or in-line with the operator's forward viewing direction depending on the vehicle passenger compartment configuration. The image display source and a spherical (or aspheric) optical combiner are used to display sensor and communications data at an optimum viewing location. A roof mounted overhead head-up display is ideal for retrofitting a vehicle passenger compartment with a virtual image display because of the simplicity and flexibility of its design. The present

invention is particularly useful as a head-up virtual image display for use in a vehicle that displays instrumentation information, and provides a vehicle head-up dynamic instrument display that provides for a virtual image instrument display at or ahead of the windshield of the vehicle. The present invention requires no mirrors and uses an optimized optical combiner surface for improved image clarity and brightness. The image display source location is ideal because there is generally ample room in the overhead area of the passenger compartment to mount equipment without interfering with an operator's field of view in any direction or his or her freedom of movement. The overhead mounted configuration requires minimal modification to the existing passenger compartment of any vehicle. The optical combiner may be roof, dashboard or windshield mounted whichever is most convenient.



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OVERHEAD HEAD-UP DISPLAY FOR VEHICLE APPLICATIONS AND THE LIKE

BACKGROUND

The present invention relates generally to virtual image display systems, and more particularly, to overhead head-up display systems for use in vehicle applications.

Vehicle instrumentation information is conventionally displayed on an instrument panel of the vehicle that is below the windshield, and requires that a driver divert
5 his or her eyes from viewing the outside scene to viewing the panel instrumentation, for example, to check vehicle speed or the status of warning lights. Such diversion requires shifting of the driver's field of view as well as refocusing, and can be a cause of inattention to a changing outside scene.

In recognition of the desirability of providing instrumentation readouts that are
10 within the line of sight of an aircraft pilot scanning the outside scene, head-up displays have been utilized in military aircraft to display instrumentation and other readouts. However, such head-up display systems are complex and expensive, and have capabilities not required in an automobile or similar vehicle.

A state-of-the-art head-up display is described in U.S. Patent No. 4,973,139,
15 entitled "Automotive Head-Up Display" issued 10/27/90, and assigned to the assignee of the present invention. U.S. Patent No. 4,973,139 discloses a head-up display system that includes an image source for producing imaging illumination, optical apparatus for directing the illumination provided by the source to a windshield of a vehicle, and a combiner that comprises a portion of the windshield for partially reflecting the directed
20 imaging illumination to produce a virtual image of the image source that is viewable by the operator of the vehicle.

More specifically, U.S. Patent No. 4,973,139 discloses a vehicle head-up instrument display including a light emitting image source for producing imaging illumination, optical apparatus for directing the imaging illumination to the inside surface of a vehicle windshield, and a combiner comprising a portion of the windshield or a coating applied to the windshield partially reflects the imaging illumination to produce a virtual image viewable by the driver. The image source and optical apparatus are enclosed in a housing having an elliptical cylindrical transparent cover for transmitting the imaging illumination to the windshield and for directing sunlight and skylight reflections therefrom away from the driver's eyes.

The invention of U.S. Patent No. 4,973,139 is also dash mounted and is relatively difficult to retrofit into existing vehicle designs and is also somewhat difficult to incorporate into new designs. Most conventional head-up displays are difficult to retrofit into existing vehicles without major dash modification or line-of-sight obstruction. The packaging design of this head-up display system is also complicated by mirrors that are employed to obtain a desired focal length between the display source and the combiner. The design also depends upon the geometric configuration of the windshield and its optical qualities. Generally, the geometric configuration of a windshield does not allow for off-axis image projection. The location of the image source in this system forces a designer to incorporate a dust cover to minimize sunlight degradation of the image.

Accordingly, it is an objective of the present invention to provide an overhead mounted head-up display that does not use a windshield or similar combiner element in the image display system and thus allows use of the present system in a wide range of applications. It is also an objective of the present invention to provide a head-up display for vehicle which produces a virtual image that is viewable by the vehicle operator without diversion of vision from the outside scene.

SUMMARY OF THE INVENTION

In order to achieve the above and other objectives, the present invention provides for a head-up display system for use in a vehicle that has its image display source located above a viewer, or vehicle operator, typically mounted adjacent the roof of the vehicle, for example. The image display source can be mounted off-axis or in-line with the viewer's or operator's forward viewing direction depending on the vehicle passenger compartment configuration. The display image source is used in conjunction with a spherical or an aspheric optical combiner to display sensor and communications data, for example, at an optimum viewing location. The spherical optical combiner is transparent and has a relatively large radius of curvature that is adjustable for displaying the

virtual image at different locations in front of the windshield of the vehicle. An aspheric combiner is used to reduce optical disparity that arises when off-axis projection is used, in lieu of a conventional dash-mounted image source location (on-axis projection). The combiner location is angularly adjustable with respect to the display source, and the operator of the vehicle to accommodate operators with different heights and that sit in different locations relative to the combiner.

The present invention is particularly useful as a head-up virtual image display system for vehicle use that displays instrumentation information, and more particularly that provides a vehicle head-up dynamic instrument display that presents a virtual image instrument display at or ahead of the windshield of the vehicle. The present invention provides a means to retrofit existing vehicles with a head-up display system to improve operator and equipment safety and efficiency. Such a head-up display system is especially useful where a vehicle operators ability to assimilate sensor and communications data are in contention with the dynamics of the environment. A roof mounted image display source is ideal for retrofitting a vehicle passenger compartment with a virtual image display system because of the simplicity and flexibility of its design.

The present invention provides an improvement to the invention disclosed in U.S. Patent No. 4,973,139. The improved head-up display system of the present invention requires no mirrors and uses an optimized optical combiner surface for improved image clarity and brightness. The location of the image display source is ideal because there is generally ample room in the overhead area of a passenger compartment to mount equipment without interfering with the operator's field of view in any direction or freedom of movement. The roof mounted configuration also requires minimal modification to the existing passenger compartment of the vehicle. The optical combiner may be roof, dash or windshield mounted, whichever is most convenient. The combiner and image source locations do not interfere with the rear view mirror or sun visor functions.

BRIEF DESCRIPTION OF THE DRAWINGS

The various features and advantages of the present invention may be more readily understood with reference to the following detailed description taken in conjunction with the accompanying drawings, wherein like reference numerals designate like structural elements, and in which:

Fig. 1 shows a top view of two embodiments of an overhead head-up display system in accordance with the principles of the present invention;

Fig. 2 shows a side view of the overhead head-up display systems of Fig. 1; and

Figs. 3 and 4 show top and side views detailing the installation of the overhead head-up display system of the present invention.

DETAILED DESCRIPTION

5 Referring to the drawing figures, Fig. 1 shows a top view of two embodiments of an overhead head-up display systems 10 in accordance with the principles of the present invention. Fig. 2 shows a side view of the overhead head-up display systems 10 of Fig. 1. Figs. 1 and 2 show a vehicle 11 having a passenger compartment and a roof 11a, and having a vehicle operator 17 occupying a seat 19 in a position to operate the vehicle 11. The vehicle 11 has a windshield 12 and a dashboard 13 that are conventional, and do not form part of the present systems 10.

A projection unit or image display source 16 is attached to the roof 11a of the vehicle 11. In one embodiment of the present system 10, the image display source 16 is disposed off-axis relative to the line of sight of the operator 17, and is shown having solid lines. The image display source 16 is thus disposed at an angle relative to the operator's forward viewing direction. In an alternative embodiment of the system 10, the image display source 16a is disposed on-axis relative to the line of sight of the operator 17, and is shown having dashed lines. The image display source 16a is thus disposed in-line with respect to the operator's forward viewing direction. The image display source 16, 16a is coupled to an electronics unit 21 by way of a cable 22. The electronics unit 21 is coupled to a battery 23 of the vehicle 11. The electronics unit 21 is adapted to control either of the display sources 16, 16a in order to couple signals for projection thereby. The electronics unit 21 may be adapted to cause the image display sources 16, 16a to project different types of image data including sensor and communications data, such as as provided by radar systems, computers, or modems, for example, or may project such image data as fuel and temperature gages, or other operating conditions of the vehicle 11, for example.

In the overhead head-up display systems 10 shown in Figs. 1 and 2, a spheric or an aspheric optical combiner 14 is provided and has a relatively large radius of curvature 15. The combiner 14 is shown attached to the windshield 12, by means of a ball and socket connection 25, for example. The combiner 14 is angularly adjustable with respect to the display source 16 and the operator 17 of the vehicle 11 to accommodate operators 17 with different heights and that sit in different locations relative to the combiner 14. The focal length between the image display source 16 and the combiner 14, as well as the spherical radius of curvature 15 of the combiner 14 is adjustable to display a virtual image 18 at different locations in front of the windshield 12 of the vehicle 11. The angle of the combiner 14 relative to the operator 17 and the image

display source 16 is also adjustable to accommodate operators with different height and seat placement. The image display source 16 is mounted on the roof 11a and the combiner 14 may be attached to the roof 11a, the windshield 12 (as is shown in the drawing figures) or the dashboard 13 (mounting provisions not shown).

- 5 The image display source 16 may comprise a cathode ray tube (CRT), a vacuum fluorescent display (VFD) or a liquid crystal display (LCD). Such image display sources 16 are currently available and may be readily employed in the present system 10. In an embodiment of the present invention that has been reduced to practice, a model RUNTK0180CEZZ manufactured by Sharp was employed. The combiner 14
10 may be made from optical grade glass or plastic depending upon the application. Optical coatings or films may be disposed on the combiner 14 to enhance the image brightness seen by the operator 17. In the embodiment of the present invention that has been reduced to practice, the combiner 14 is made of polycarbonate and its concave surface is coated with a broadband visible coating, and its convex surface is coated with
15 magnesium fluoride antireflective coating. A mathematical equation defining the concave surface that is well-understood by optical designers is given by

$$Z = - \left(R_x - \sqrt{(R_y - \Delta)^2 - X^2} \right), \text{ where } \Delta = \frac{Y^2}{R_y - \sqrt{R_y^2 - Y^2}}$$

- Figs. 3 and 4 show top and side views detailing the installation of the overhead head-up display system 10 of the present invention. The distances between
20 components and angles between optical rays indicated on these drawing figures are those used in a typical automobile installation.

- The overhead head-up display systems of the present invention have broad application to large numbers of commercial and military systems. Mobile and stationary equipment requiring an operator-monitored or controlled interface may benefit from
25 the use of the present invention.

- Thus, there has been described new and improved overhead head-up display systems. It is to be understood that the above-described embodiments are merely illustrative of some of the many specific embodiments which represent applications of the principles of the present invention. Clearly, numerous and other arrangements can
30 be readily devised by those skilled in the art without departing from the scope of the invention.

What is claimed is:

1. A head-up display system for use in a vehicle having a windshield, a passenger compartment, and a roof, and wherein the head-up display system is adapted to project a virtual image for viewing by an operator of the vehicle, said system comprising:
 - 5 a display source that is disposed in the passenger compartment adjacent the roof of the vehicle and above the operator of the vehicle; and
 - a combiner having a relatively large spherical radius of curvature, and wherein the radius of curvature is adjustable to provide for the display of a virtual image at different locations in front of the windshield of the vehicle, and wherein the combiner
 - 10 is disposed at an adjustable angle with respect to the display source and the operator of the vehicle, in order to accommodate operators having differing heights and that sit at different locations relative to the combiner.
2. The head-up display system of Claim 1 wherein the display source is disposed off-axis and at an angle relative to a forward viewing direction of the operator.
3. The head-up display system of Claim 1 wherein the display source is disposed in-line with respect to a forward viewing direction of the operator.
4. The head-up display system of Claim 1 wherein the display source is disposed on an inside surface of the roof of the vehicle and the combiner is disposed on an inside surface of the roof of the vehicle.
5. The head-up display system of Claim 1 wherein the display source is disposed on an inside surface of the roof of the vehicle and the combiner is disposed on the windshield of the vehicle.
6. The head-up display system of Claim 1 wherein the display source is disposed on a roof of the vehicle and the combiner is disposed on a dashboard of the vehicle.
7. The head-up display system of Claim 2 wherein the display source is disposed on an inside surface of the roof of the vehicle and the combiner is disposed on an inside surface of the roof of the vehicle.

8. The head-up display system of Claim 2 wherein the display source is disposed on an inside surface of the roof of the vehicle and the combiner is disposed on the windshield of the vehicle.

9. The head-up display system of Claim 2 wherein the display source is disposed on an inside surface of the roof of the vehicle and the combiner is disposed on a dashboard of the vehicle.

10. The head-up display system of Claim 3 wherein the display source is disposed on an inside surface of the roof of the vehicle and the combiner is disposed on an inside surface of the roof of the vehicle.

11. The head-up display system of Claim 3 wherein the display source is disposed on an inside surface of the roof of the vehicle and the combiner is disposed on the windshield of the vehicle.

12. The head-up display system of Claim 3 wherein the display source is disposed on an inside surface of the roof of the vehicle and the combiner is disposed on a dashboard of the vehicle.

13. The head-up display system of Claim 1 wherein the combiner is a spherical combiner.

14. The head-up display system of Claim 1 wherein the combiner is an aspherical combiner.

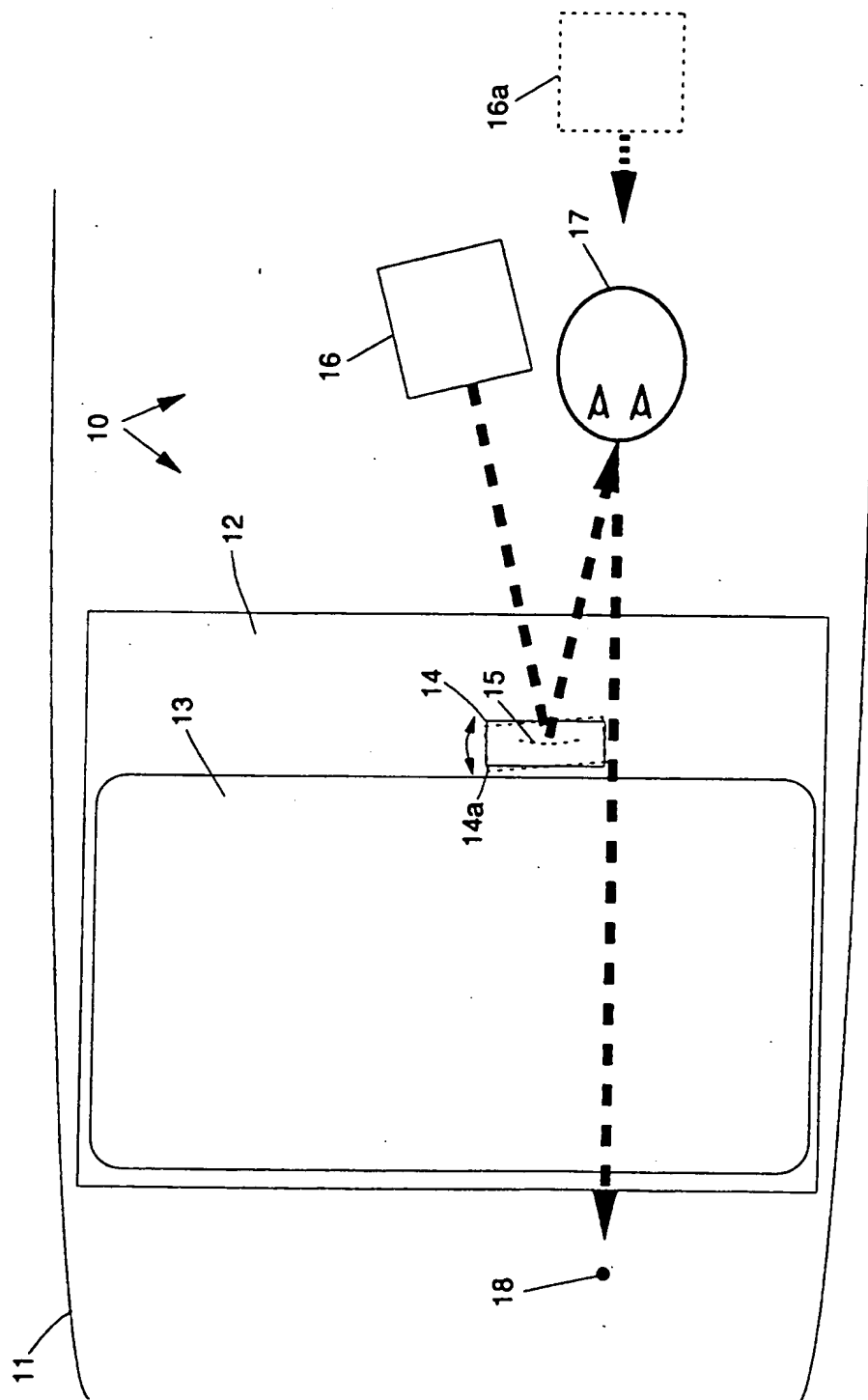


FIG. 1

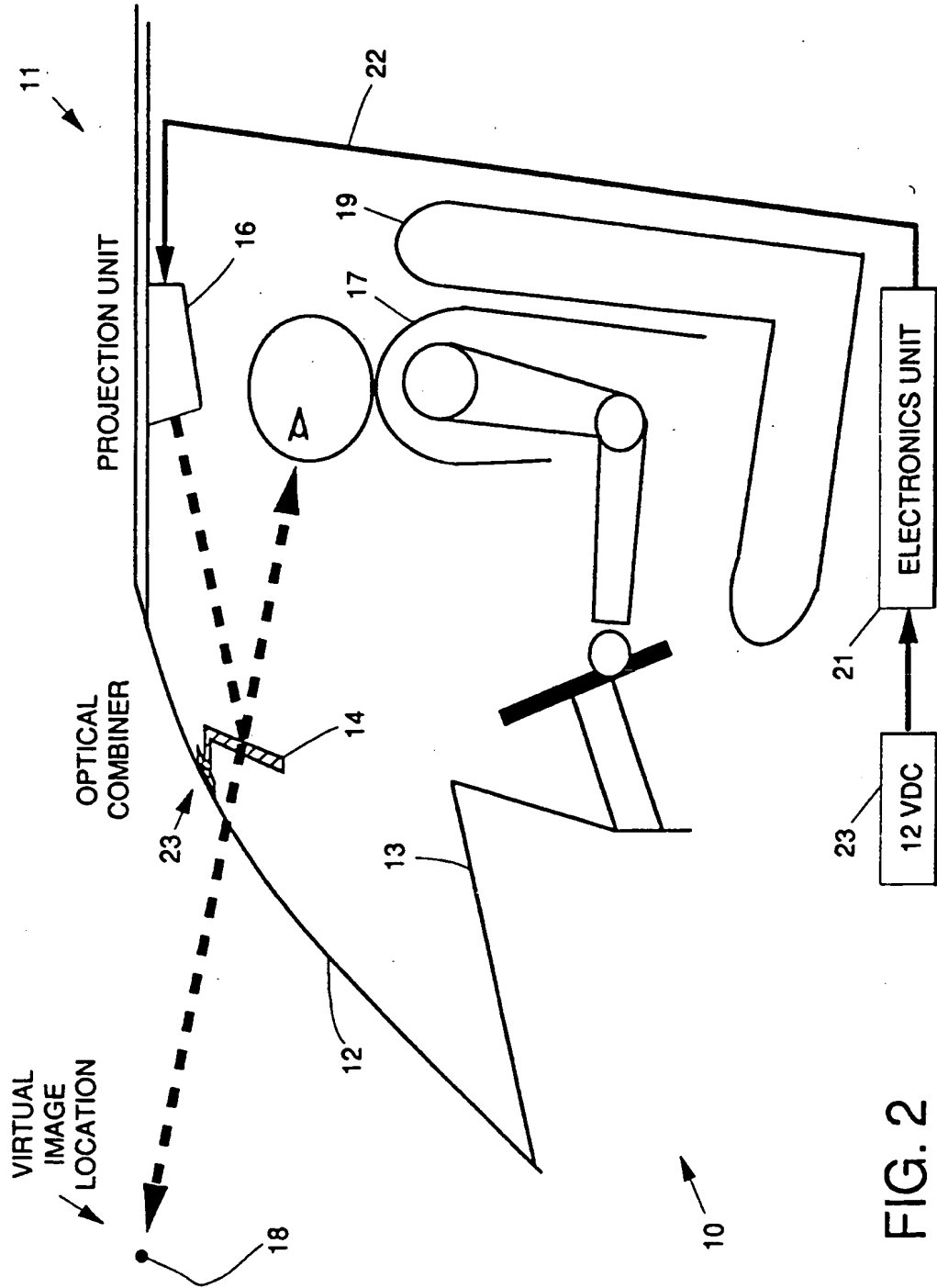
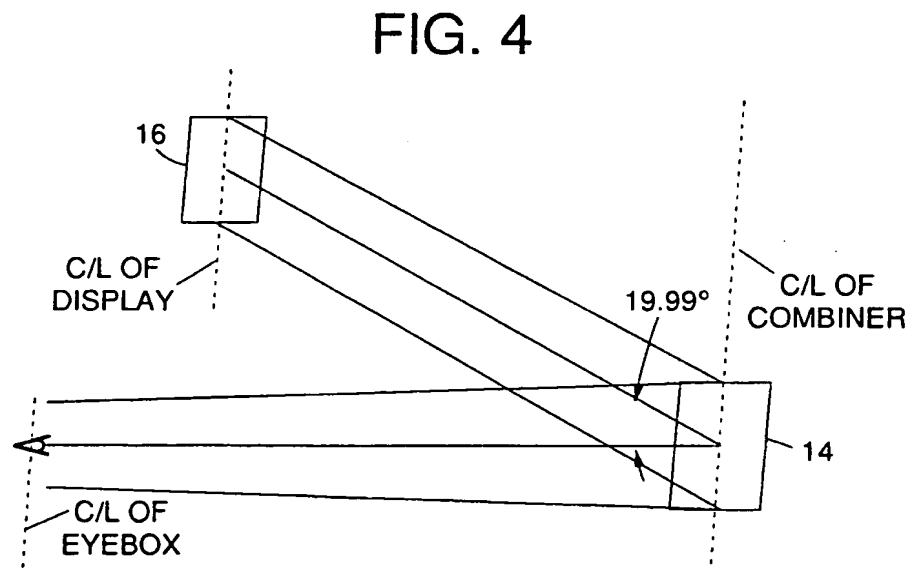
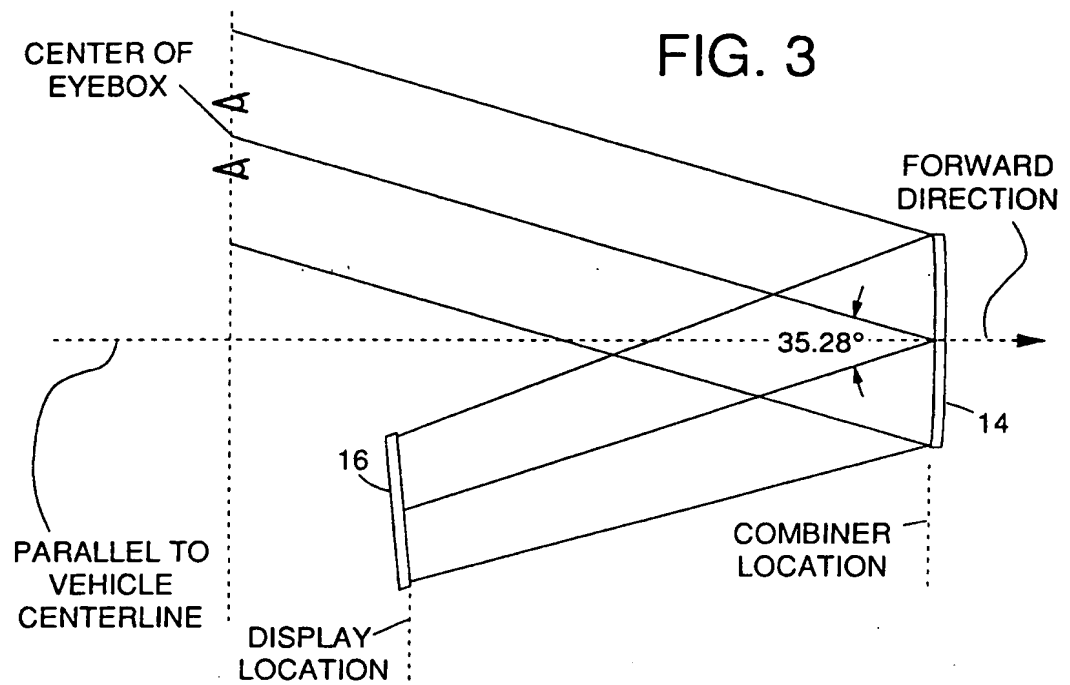


FIG. 2



INTERNATIONAL SEARCH REPORT

Int. Application No

PCT/US 93/08904

A. CLASSIFICATION OF SUBJECT MATTER

IPC 5 G02B27/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 5 G02B F21V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,4 831 366 (IINO) 16 May 1989 see abstract; figure 3 see column 2, line 61 - line 64 see column 5, line 7 - line 14 ---	1,4-12
A	US,A,4 188 090 (ELLIS) 12 February 1980 see column 2, line 57 - line 61; figure 1 see column 3, line 49 - line 58 see column 4, line 11 - line 17 ---	1,4-12
A	EP,A,0 450 553 (YAZAKI) 9 October 1991 see column 4, line 13 - line 25; figure 1 ---	1,4-12
A	WO,A,91 00674 (AUTOVISION) 10 January 1991 see page 6, line 9 - line 13; figure 1 --- -/--	1,4-12

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

14 January 1994

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NL - 2280 HV Rijswijk
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SOULAIRE, D

INTERNATIONAL SEARCH REPORT

Int. Patent Application No
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

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